

Effect of grazing intensity on the habitat of *Shijimiaeoides divinus asonis* (Matsumura) (Lepidoptera, Lycaenidae)

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Abstract The population of a lycaenid, *Shijimiaeoides divinus asonis* (Matsumura) has been reduced by environmental changes in some habitats in the Aso area. We conducted route census surveys of this butterfly in 2006 and 2007. The study area is located on the volcanic slopes of Mt Aso in the center of Kyushu, Japan. At the study site, the natural herbaceous grassland, which had been almost completely grazed, was subjected to routine grassland burning every spring. The results obtained are summarized as follows: (1) *Pleioblastus chino* (Franch. et Savat.) Makino var. *viridis* (Makino) S. Suzuki was one of the dominant species at the study sites with normal grazing intensity. *Zoysia japonica* Steud. was one of the dominant species with high grazing intensity. On the other hand, *Miscanthus sinensis* Anderss. was the dominant species at non-grazing sites. (2) The individual density of the host plant, *Sophora flavescens* Ait. was significantly different at each study site. (3) The height of the host plant at the non-grazing sites was higher than at other study sites. (4) The number of branches of the host plant at the sites with normal grazing intensity was larger than at other sites. (5) The individual crown area was bigger at the sites with normal grazing. On the other hand, the height and crown area of the host plant at sites with high grazing intensity was smaller than at sites with other grazing intensities. (6) Adult butterflies appear in early May almost disappear by mid June. Individual numbers were affected by low temperatures from April to May, and the density of butterflies markedly decreased in 2007 at all study sites. (7) The number of larvae was significantly different at each study site when population density became high. (8) The number of adults and eggs increased alongside an increase in the number of nectar plants at the grassland where grazing ceased. Based on these results, it is concluded that customary grazing intensity is most suitable for the conservation of this butterfly in the Aso area.

Key words Pasturage, grassland, *Shijimiaeoides divinus asonis*, large shijimi blue, conservation.

Introduction

The lycaenid, *Shijimiaeoides divinus asonis* (Matsumura), is one of the rarest butterflies in Kyushu, only found on limited areas of the volcanic slopes of Mt Aso. The larva feeds on flower buds of *Sophora flavescens* Ait. The grassland has been managed as meadows by farmers for several hundred years. This lycaenid was designated in 1995 as a National Endangered Species in the Law for the Conservation of Endangered Species of Wild Fauna and Flora legislated by the Environment Agency of Japan. Recently, numbers of this butterfly have been reduced by environmental changes in some habitats in the Aso area. Our previous study showed that habitat change factors can be divided into four groups; human effect, grassland management, volcanic activity and climate (Murata & Nohara, 1993). Habitat change caused declines of attendant ants, host plant and nectar plants, and increases in some natural enemies, and these phenomena resulted in the decline of the butterfly populations (Murata & Nohara, 1993; Murata *et al.*, 1998; Murata & Nohara, 2001, 2003, 2005).

On the other hand, the population of the butterfly has not been declining in areas where routine grassland burning has taken place (Murata *et al.*, 1998). Routine grassland burning

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seems to have a positive influence on the butterfly population. Traditional grassland burning and continuous grazing are important for the sustainable conservation of the butterfly.

Recent studies have reported that how the patterns of species diversity of butterflies change along a gradient of human economic disturbance (Balmer & Erhardt, 2000; Kitahara & Sei, 2001; Inoue, 2003; Nisinaka & Ishii, 2006). However, it was not clear how the grazing intensity affects the habitat and the population of this butterfly.

This paper reports an investigation conducted to make clear the effect of grazing intensity on abundance of the butterfly, on the density of the host plant and on the nectar plant flora used by this butterfly in the Aso area.

Location, study sites and methods

a) Location and study sites

The study area is located on the volcanic slopes of Mt Aso. Three sites (A–C) with different grazing intensities were surveyed in the butterfly habitats (Fig. 1). All study sites, routine grassland burning was carried out every spring. At all study sites were classified as grassland mainly covered with natural herbaceous plants. At site A, grazing intensity (days/animal unit) was normal for the Aso area, and at site B, grazing had been stopped since 1998 at site B. At site C, grazing intensity was higher than at site A, consequently constituting the highest intensity of the three sites. At each study site grazing intensity remained unchanged from 2000 to 2007.

b) Density of *S. flavescens* and nectar plants

The density, branch number, individual crown area and plant height of *S. flavescens* were measured in three main quadrats (5 m×5 m) randomly established in each study site.

c) Dominant ratio of nectar plants

The extended summed dominant ratios of nectar plant of this butterfly and plant height were measured in nine subquadrats (1 m×1 m) randomly established in each main quadrats at all study sites using the Penfound and Howard method. The dominant ratio of the plants was calculated using E-SDR₂.

d) Quantification of the adult butterfly, egg and larva

The number of adult butterflies was recorded by route census surveys for 10 minutes (500 m in distance) from 10:30 to 13:00 hrs local time under fine weather conditions during the adult flight season (from April to June) (Murata & Nohara, 2001, 2003, 2005).

Eggs and larvae were counted on 50 shoots of the host plant once a week from May 15 to June 26 at all study sites in 2006 and 2007.

e) Influence of the grazing intensity on the adult and egg population

Two quadrats (200 m×200 m, site G and site NG) were surveyed at site C in 2006 and 2007 (Fig. 2). In 2006, grazing occurred at both sites, however, in 2007, grazing did not occur at site NG but was normal at site G. These study sites was adjacent to each other.

The number of adult butterflies was recorded by route census surveys for 5 minutes (250 m in distance) from April to July at site G and site NG in 2006 and 2007. The density of eggs was counted on 25 shoots of the host plant which were selected at random at both sites in 2007.

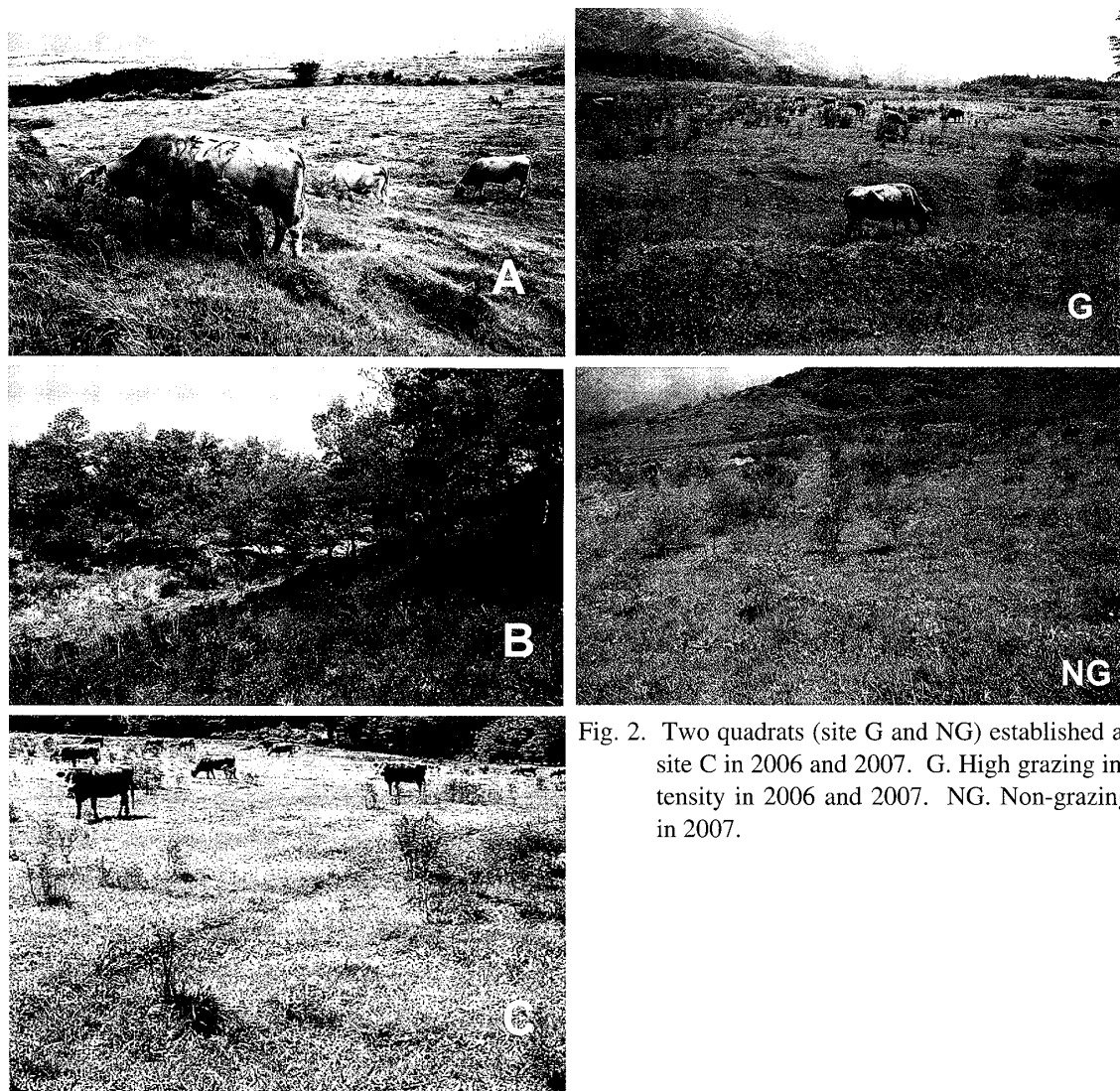


Fig. 1. The study sites under different grazing intensities. A. Normal grazing intensity. B. Non-grazing. C. High grazing intensity.

Fig. 2. Two quadrats (site G and NG) established at site C in 2006 and 2007. G. High grazing intensity in 2006 and 2007. NG. Non-grazing in 2007.

Results

1. Influence of grazing intensity on growth of host plant

The landscapes of the study sites were remarkably different dependent on the pattern of grazing (Fig. 1). The degree of plant cover was low at site G under high grazing intensity in 2006 and 2007 (Fig. 2). Table 1 shows the properties of *S. flavescens* population. The individual density of the host plant was significantly different at each study site (Tukey-Kramer's test, $p < 0.05$). The height of the host plant at site B (non-grazing) was significantly higher than at sites A (normal grazing) and C (high grazing) (Tukey-Kramer's test, $p < 0.05$). The individual crown area at sites A and B was bigger than at site C. The branch number of host plants at site B was larger than at sites A and C.

2. Influence of grazing intensity on vegetation

Table 2 shows the degree of cover of the dominant grass species (E-SDR₂). *Zoysia japonica*

Table 1. Properties of *Sophora flavescens* population.

Property	Study sites		
	A	B	C
Stocking density (animal unit/ha)	1.1	0	1.4
Individual density (/25 m ²)	23.0 ± 8.9 ^a	4.7 ± 4.6 ^c	13.7 ± 11.1 ^b
Branch number (/individual)	5.5 ± 1.0 ^a	11.1 ± 9.6 ^a	5.0 ± 0.2 ^a
Individual crown area (100 cm ²)	33.3 ± 12.9 ^a	27.0 ± 16.1 ^a	16.8 ± 2.7 ^a
Plant height (cm)	81.9 ± 13.1 ^a	105.8 ± 17.2 ^a	70.2 ± 13.2 ^{ab}

Data were obtained in September.

Different letters in the same line show significant difference at 5% levels by Turkey-Kramer's test.

Table 2. Cover degree (E-SDR₂) of dominant species.

Species of dominance	Study sites		
	A	B	C
Grazing intensity (days/animal unit-ha)	190	0	250
<i>Sophora flavescens</i>	42.6	39.7	31.6
<i>Pleioblastus chino</i> var. <i>viridis</i>	50.1	—	—
<i>Miscanthus sinensis</i>	—	89.0	—
<i>Imperata cylindrica</i> var. <i>koenigii</i>	—	59.4	—
<i>Lespedeza striata</i>	27.9	—	—
<i>Zoysia japonica</i>	—	—	52.5
<i>Arundinella hirta</i>	—	—	15.1

Data were obtained in September.

Steud. (E-SDR₂ 52.5) was most dominant at site C (high grazing). *Miscanthus sinensis* Anderss. (E-SDR₂ 89.0) was dominant at site B (non-grazing). On the other hand, *P. chino* (Franch. et Savat.) Makino var. *viridis* (Makino) S. Suzuki (E-SDR₂ 50.1) and *S. flavescens* (E-SDR₂ 42.6) were dominant species at site A (normal grazing). The higher the grazing intensity, the lower the E-SDR₂ of *S. flavescens* tended to be.

Among nectar sources, *Cirsium japonicum* DC. was dominant at sites A and B, and *Viola mandshurica* W. Becker was the most dominant species at site C (Table 3). The dominant ratios of nectar plants at site A were significantly higher than at site C.

3. Influence of grazing intensity on the number of adults

Seasonal fluctuations of adults, rainfall, and air temperature were measured in 2006 and 2007 (Fig. 3). Mean air temperature was similar between 2006 and 2007 except for mid April. The total amount of rainfall was greater in 2006 than 2007. Butterflies were found at all study sites from late April to early June. The peak occurred in middle of May. The number of the butterfly markedly decreased at all sites in 2007. A larger number of the butterflies was recorded at site A than at sites B and C in 2006 and 2007.

4. Influence of grazing intensity on the number of eggs

The number of eggs was monitored from late May to early June in 2006 and the latter May in 2007, respectively (Fig. 4). The seasonal change in the number of eggs coincided with that in the number of adults in both years. Table 4 shows the density of larvae in 2006 and 2007. The density of larvae was significantly different between site A and sites B–C on 6 and 13 June in 2006 when population was high (Tukey-Kramer's test, $p < 0.05$).

Figure 5 shows seasonal fluctuations of eggs at site NG (non-grazing) and site G (grazing). The number of eggs at site NG was greater than at site G on 22 and 27 May, 2007 (Fig. 5).

Table 3. Extended summed dominant ratios of host plant and nectar plants for *Shijimiaeoides divinus asonis* in each plant community.

	Species	Study sites					
		A		B		C	
Host plant	<i>Sophora flavescens</i>	56.1 ±	1.7 ^a	47.8 ±	9.2 ^{ab}	36.6 ±	19.6 ^{ab}
Nectar plants	<i>Cirsium japonicum</i>	7.6 ±	1.6 ^a	4.9 ±	4.1 ^{ab}	0.4 ±	0.6 ^b
	<i>Viola mandshurica</i>	2.6 ±	0.4 ^a	3.0 ±	3.8 ^a	2.6 ±	0.8 ^a
	<i>Viola grypoceras</i>			0.2 ±	0.3 ^a		
	<i>Viola verecunda</i>	1.7 ±	3.0 ^a			0.2 ±	0.4 ^a
	<i>Viola sieboldii</i>	1.0 ±	0.4 ^a				
	<i>Senecio integrifolius fauriei</i>			1.4 ±	1.6 ^a		
	<i>Elaeagnus umbellata</i>	1.7 ±	2.9 ^a				
	<i>Ranunculus japonicus</i>					0.4 ±	0.5 ^a
	<i>Trifolium repens</i>						
Total		70.6 ±	3.4 ^a	57.2 ±	3.8 ^{ab}	40.2 ±	19.7 ^{bc}
Total without <i>Sophora flavescens</i>		14.6 ±	5.0 ^a	9.4 ±	5.4 ^{ab}	3.6 ±	0.2 ^b

Data show mean±standard deviation. Data were obtained in June–July.

Different letters in the same line show significant different at 5% levels by Turkey-Kramer's test.

The number of adults at site NG was three times as high as at site G in 2007 (Fig. 6). At site NG, the density of *Senecio nemorensis* L., one of the nectar plants, was greater than at site G (Fig. 2).

Discussion

Effect of grazing intensity on butterfly population

Secondary grassland, which is one of the main landscape element types, has been main-

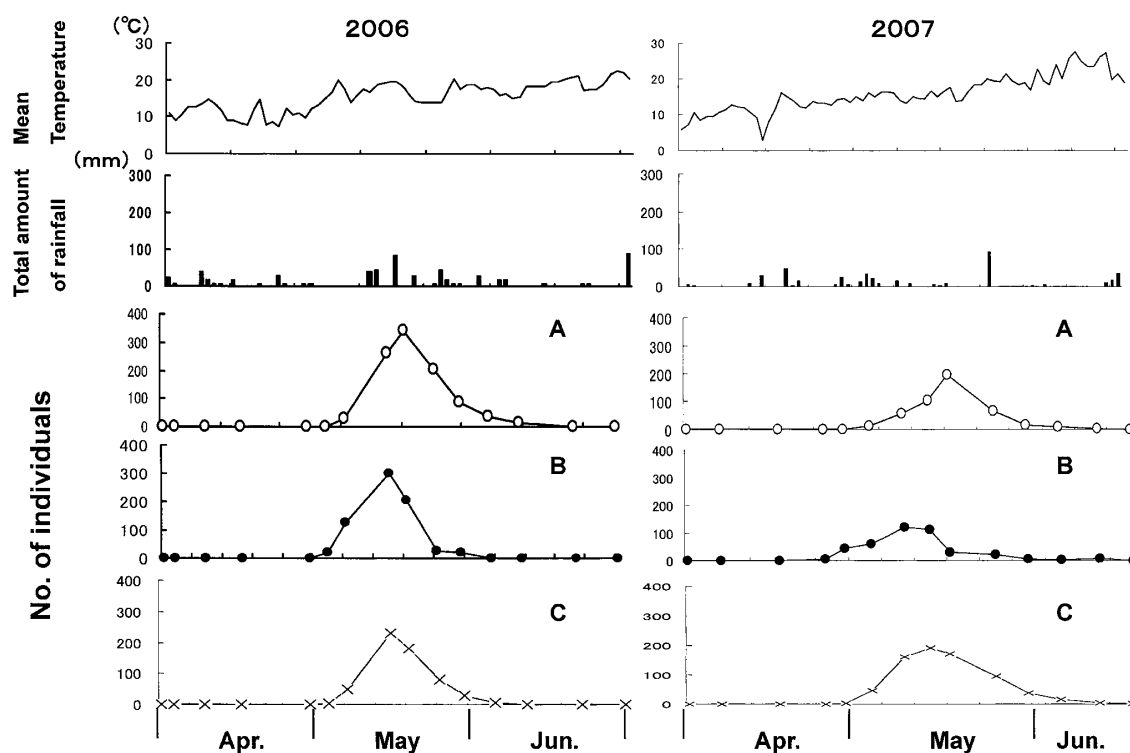


Fig. 3. Seasonal changes of mean temperature, total amount of rainfall and the adult number of *Shijimiaeoides divinus asonis* at three study sites.

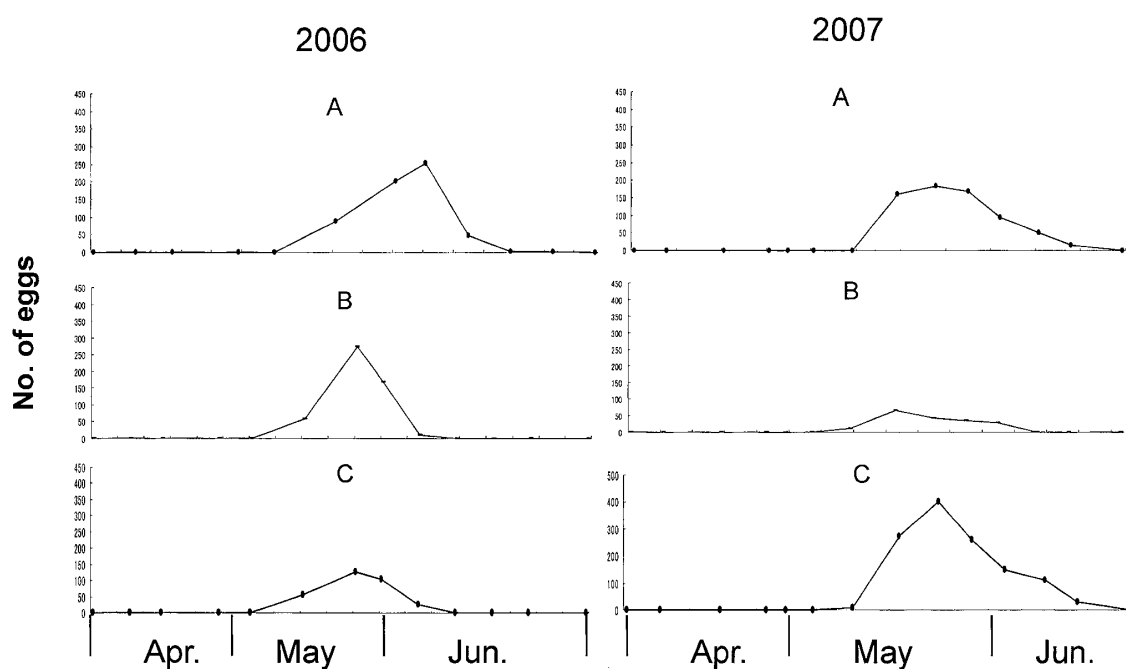


Fig. 4. Seasonal changes in the number of eggs on each site.

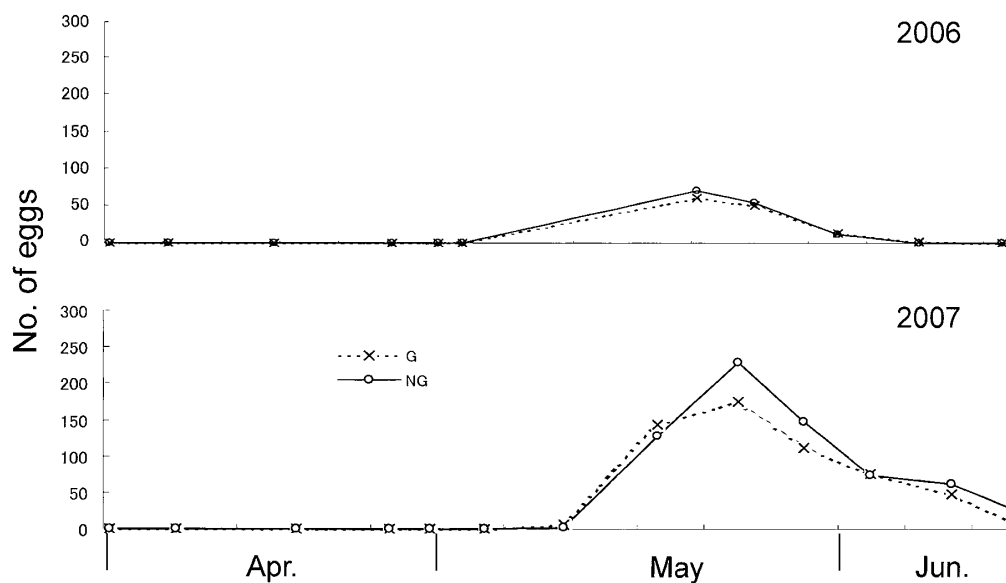


Fig. 5. Seasonal changes in the number of eggs at site C in 2006 and 2007. G: Grazing in 2006 and 2007; NG: Grazing in 2006, non-grazing in 2007.

tained by traditional mowing and grazing in the Aso area. Farmers and cow-breeders have burned these grasslands every spring for several hundred years ago (Murata & Nohara, 1993).

The larval host plant, *S. flavesens* has not been affected of grassland burning because the host plant is perennial. Burning promote germination of some plants, not including *S. flavesens* (Murata *et al.*, 1998). The number of eggs, larvae and attendant ants decreased and the populations of some kinds of natural enemies increased when burning of grassland

Table 4. Number of larvae of *Shijimiaeoides divinus asonis* on 10 shoots of *Sophora flavescens*.

Date of survey		Study sites		
		A	B	C
2006	25 May	0	0	0
	6 June	1.14 ^a ± 1.31	0.48 ^b ± 0.68	0.66 ^b ± 0.98
	13 June	2.14 ^a ± 1.48	1.34 ^b ± 1.15	1.54 ^b ± 1.54
	20 June	3.76 ^a ± 5.37	0.28 ^c ± 0.54	1.80 ^b ± 2.69
	27 June	1.4 ^a ± 0.55	0 ^a	0 ^a
2007	22 May	0 ^a	0.06 ^a ± 0.09	0 ^a
	27 May	0 ^a	0.04 ^a ± 0.09	0 ^a
	1 June	0 ^b	0.08 ^a ± 0.04	0.02 ^{ab} ± 0.04
	7 June	0.36 ^a ± 0.41	0.06 ^a ± 0.09	0.36 ^a ± 0.41
	12 June	0.48 ^a ± 0.41	0.06 ^a ± 0.09	0.48 ^a ± 0.41
	21 June	1.10 ^a ± 0.79	0 ^b	1.10 ^a ± 0.79
	27 June	0.20 ^a ± 0.16	0 ^a	0.20 ^a ± 0.16

Different letters in the same line show significant different at 5% levels by Turkey-Kramer's test.

stopped (Murata & Nohara, 2003). Therefore, grassland burning may be an important factor in the conservation of this butterfly. Many rare butterflies require vegetation management (grazing, mowing etc.) for populations to be maintained effectively (New, 1997).

However, New *et al.* (1995) reported that rare butterflies may also exhibit narrow tolerances for management types for their habitats, more so than the flora they depend on. How does the grazing intensity affect the population of the butterfly? The butterfly habitats were mainly covered with natural herbaceous plants.

The dominant species were *Z. japonica* at site C (high grazing intensity), *M. sinensis* at site B (non-grazing) and *P. chino* var. *viridis* and *S. flavescens* at site A (normal grazing intensity), respectively.

Kira (1952) reported the effect of grazing intensity on vegetation in the Aso area. In his report, *M. sinensis* was the dominant species under grazing intensity of 0.5 animal unit/ha, *P. chino* var. *viridis* was dominant under grazing intensity of 0.6–1.0 animal unit/ha, *Z. japonica* was dominant under grazing intensity over 1.5 animal unit/ha.

In our survey, the degree of cover of *P. chino* var. *viridis* and *S. flavescens* at site A (under 1.1 animal unit/ha) was also higher than for other species. At site B (0 animal unit/ha), the cover degree of *M. sinensis* was also highest, and at site C (1.4 animal unit/ha), the cover degree of *Z. japonica* was highest. These results are similar to those of Kira (1952). He did

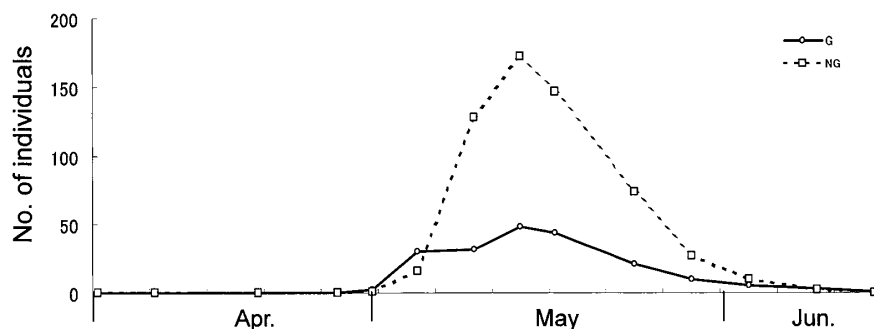


Fig. 6. Seasonal changes in adult numbers at site C in 2007. G: Grazing; NG: Non-grazing.

not mention *S. flavesens*: however, our results suggest that there is some optimal grazing intensity for *S. flavesens*. The population of this butterfly was highest at site A (1.1 animal unit/ha) where the degree of cover of the host plant was the highest between the three sites. These results suggest that maintenance of the optimal grazing intensity is important for conservation of this butterfly.

Effect of grazing intensity on nectar plants

There are thirteen species of nectar plants for this butterfly in the Aso area (Murata & Nohara, 2001). It is important to conserve these nectar plants for this butterfly. However, the effect of grazing intensity on the quantity of nectar plants was not clear. In this survey, the population of *C. japonicum* was higher where the degree of cover of the host plant was lower. The degree of cover of *V. mandshurica* was high at site B where grazing did not occur. These results suggest that grazing intensity may be the important factor for the growth of nectar and host plants

Influence of grazing intensity on the number of adults and eggs

There was no significant difference in the number of eggs between site G and site NG in 2006. In 2007, the adult number at site NG was three times greater than at site G (Fig. 6). The egg number at site NG was also greater than at site G (Fig. 5). These results may be explained by the density of *S. nemorensis*, whose density at site NG was much greater than at site G in 2007. These results suggest that higher grazing might suppress the growth of some kinds of nectar plants.

Effect of grazing intensity on the growth of host plant

Distribution of *S. flavesens* was not uniform in the Aso area (Murata and Nohara, 1993). In our results, the population of *S. flavesens* was higher at sites A and C than site B. There were significant differences in the population of *S. flavesens* at each survey site. Crown size of host plants was larger at site A than sites B and C, and the branch number of host plants was also larger at site A (normal grazing intensity) than at other sites. A bigger crown size of the host plant may increase the availability of buds for larvae. It is suggested that the host plants were able to grow larger in an open situation providing sufficient sunlight as a result of burning and optimal grazing intensity. In contrast, the height of the host plant was low under high grazing intensity (site C) because cows directly destroy the host plant. Furthermore, at site B (non-grazing), the height of the host plants was taller and the crown size smaller because of the high population density of tall grasses.

In conclusion, it may be important to keep grazing intensity around 190 days/animal unit-ha for conservation of butterfly habitat through the maintenance of grassland in the Aso area.

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摘 要

オオルリシジミの発生に及ぼす放牧圧の影響 (村田浩平・岡本智伸・松浦朝奈・岩田眞木郎)

阿蘇地域に生息するオオルリシジミ *Shijimiaeoides divinus asonis* の個体数は、その生息環境の変化により幾つかの生息地では減少傾向にある。本研究では、本種の発生や食草、蜜源植物相に及ぼす放牧圧の影響を明らかにするため、生息地の植生を明らかにすると共に、食草や蜜源植物の密度と本種の発生および密度について慣行的な放牧圧である草原と、高い放牧圧の草原、休牧中の草原について調査を行った。生息地は、毎春、野焼きが実施されてきた阿蘇地域の半自然草地である。本調査を実施し、得られた結果は次の通りである。

(1) 本種の生息地の植生と放牧の関係进行调查したところ、阿蘇地域の慣行的な放牧圧である調査地では、ネザサ *Pleioblastus chino* var. *viridis* が最優占種であったが、放牧圧が高い調査地では、シバ *Zoysia japonica* が最優占種であった。また、休牧中の調査地では、ススキ *Miscanthus sinensis* が最優占種となり、放牧圧は、生息地の植生に影響を及ぼしていることが示された。(2) 食草であるクララ *Sophora flavescens* の被覆度 (E-SDR₂) は、高い放牧圧区に比べて阿蘇地域の慣行的な放牧圧で高かった。(3) クララの草丈は、休牧中の調査地において高い傾向が見られた。(4) クララの分枝数は、慣行的な放牧圧である調査地において多かった。(5) クララのクラウン面積は、慣行的な放牧圧である調査地において大きかった。一方、高い放牧圧では、クララのクラウン面積と草丈は小さくなる傾向が見られた。(6) 本種の成虫は、5月上旬に出現し、6月中旬に見られなくなった。2007年の本種成虫の個体数は、4月から5月にかけての低温の影響を受け、2006年に比べて全ての調査地で低く推移した。(7) 幼虫密度が高いとき、幼虫数は、調査地ごとに違いが認められ、幼虫の密度に放牧圧が影響を及ぼしている可能性が示唆された。(8) これまで野焼き、放牧を継続的に実施してきた草地で休牧すると、蜜源植物が増加し、本種の成虫数、卵数を増加させることが示唆された。これらの結果から、阿蘇地域において本種を保護するために最適な放牧圧は、同地域における慣行的な放牧圧であることがわかった。

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